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For:

SYSTEM AND METHOD FOR OPTIMAL SETTING OF
MESSAGE ACCEPTANCE FILTERS

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SYSTEM AND METHOD FOR OPTIMAL SETTING OF MESSAGE ACCEPTANCE FILTERS

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TECHNICAL FIELD

The present invention relates generally to the field of network communication. More specifically, the present invention relates to systems that utilize mask/value filters to specify acceptance parameters wherein messages are accepted based on an identifying number contained in the message.

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BACKGROUND OF THE INVENTION

Network communication exists in various forms. One specific form is to utilize message accept/reject filters. In such a system, messages are accepted or rejected based on an identifying number contained in the message that matches (accept) or does not match (reject) a mask or value filter.

Devices connected within a communication network utilizing message acceptance filters will facilitate communication among each other by including a message identifier within each transmitted message. From the device perspective, the message identifier determines whether or not an incoming message is addressed to it. If so, the device will accept/filter the message and process the data. If not, the message will be rejected.

Filtering of the message can generally be accomplished in a variety of ways. In one technique, the module can either refuse the unwanted messages by implementing hardware filters. In another technique, all the wanted messages are initially accepted and then the unwanted messages are rejected via a software filtering process.

Software filtering has at least two drawbacks. One of which is a possible overload of the input buffers in the device. Another software shortcoming is the supplementary CPU activity required in such filtering. Hardware filters can also consume a great amount of time and CPU capacity.

Generally, message identifiers are chosen such that the filter can be chosen simply. However in some cases, e.g., ST7 microprocessors, the message identifiers and

5 the filters have been prescribed and are not capable of being modified. In such a inflexible network, it is desirable to create a system capable of accepting all desired messages and rejecting the optimal amount of unwanted messages.

This invention is designed to solve these and other problems.

10 **SUMMARY OF THE INVENTION**

The present invention is directed to a method for improving network communication utilizing acceptance filters. More specifically, one embodiment of the present invention provides a method for optimizing communication in a network.

Communication on the network involves wanted and unwanted messages wherein a set of

15 filters are configured to accept all wanted network messages and minimize the acceptance of unwanted messages in accordance with a selection criteria. The method comprises configuring a first filter to receive all wanted messages. The first filter includes a defined bit and an undefined bit. Each defined bit is either in a first state or in a second state. A second filter is set equal to the first filter. The first filter and the second filter compose a first set of filters. Potential configurations of the first set of filters are determined where each potential configuration of the first set of filters is capable of accepting all wanted network messages. Each potential configuration of the first set of filters is optimized to reduce acceptance of unwanted messages while continuing to ensure acceptance of all wanted messages.

20 25 A further aspect of the present invention includes selecting an optimum configuration of the first set of filters in response to a selection criteria. The optimum configuration of the first set of filters is selected from the potential configurations of the first set of filters.

An object of the present invention is to provide a method of improving the 30 efficiency of hardware filters and reduce the accompanying complexity to set them.

Another object of the present invention is to determine the optimal configuration of a message acceptance filter for improving network communication.

Yet another object of the present invention is to provide a method of facilitating communication among operably connected devices on a network having prescribed and 35 fixed message identifiers.

5 Other features and advantages of the invention, which are believed to be novel and nonobvious, will be apparent from the following specification taken in conjunction with the accompanying drawings in which there is shown a preferred embodiment of the invention. Reference is made to the claims for interpreting the full scope of the invention which is not necessarily represented by such embodiment.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a communication network;
FIG. 2 is a lock diagram of the internals structure of a device connected to the communication network; and,

15 FIG. 3 is a block diagram of the filter structure of one embodiment of the present invention.

DETAILED DESCRIPTION

20 Although this invention is susceptible to embodiments of many different forms, a preferred embodiment will be described and illustrated in detail herein. The present disclosure exemplifies the principles of the invention and is not to be considered a limit to the broader aspects of the invention to the particular embodiment as described.

25 Referring to FIGS. 1 and 2, devices 12 on a network 10 communicate with each other by sending messages 14 having a message identifier 16 over a communication bus 18. From the perspective of each device 12, the message identifier 16 determines whether or not an incoming message is addressed to the device. If so, the device 12 will filter/accept the message and process the accompanying data. If not, the message will not be accepted.

30 The acceptance of the message 14 is accomplished through filtering. One filtering technique utilizes hardware filters to reject an unwanted message. Another filtering technique accepts all the messages and implements a software filter to later reject the unwanted message. FIG. 3 depicts one embodiment of a filter structure. Messages 14 are received at the filters 20 from the communication bus 18 and are processed to the CPU, registers, etc.

5 Both software and hardware filters have drawbacks. For software, the input buffers of the devices can be overloaded due to the acceptance of all the messages 14. Additionally, CPU activity may need to be supplemented. For hardware, the setting of the hardware filters can consume a great deal of time and CPU resources. The present invention proposes an embodiment comprised of both hardware and software filters.

10 More specifically, a system and method are described to set the hardware filters in an effective manner. Although the final result may be less than optimal, the results, both in the savings of processing and time, are significantly better than the results of past techniques.

One embodiment of the present invention provides a method for optimizing communication in a network. Communication on the network involves wanted and unwanted messages wherein a set of filters are configured to accept all wanted network messages and minimize the acceptance of unwanted messages in accordance with a selection criteria. The method comprises configuring a first filter to receive all wanted messages. The first filter includes a defined bit and an undefined bit. Each defined bit is either in a first state or in a second state. A second filter is set equal to the first filter. The first filter and the second filter compose a first set of filters. Potential configurations of the first set of filters are determined wherein each potential configuration of the first set of filters is capable of accepting all wanted network messages. Each potential configuration of the first set of filters is optimized to reduce acceptance of unwanted messages while continuing to ensure acceptance of all wanted messages.

Network messages include an identifier, m , having a size of n bits, e.g., $m = m_n, m_{n-1}, m_{n-2}, \dots, m_1, m_0$. M_w represents a set of wanted messages in the bus 18 and M_p represents a set of possible messages on the bus. F is a set of filters, i.e., $\{F_1, F_2, F_3, \dots, F_i\}$ wherein F_i is the i th filter, e.g., $F_i = f_{n-1}, f_{n-1} \dots f_1, f_0$; and each filter has three possible settings: match, no match, and don't care, i.e., $f_j = \{1, 0, X\}$.

For a filter F_i , a message m will be accepted if and only if each bit, $m_j, j = 0, 1, \dots, n-1$; is equal to f_j , unless $f_j = X$, the don't care state. The equation below is shown to relate the concept that a filter be configured to accept at least all the wanted messages. That is, for ($j = 0, j < n, j++$)

35 { if (($f_j == X$) or ($f_j == m_j$)) {do not reject and continue}

5 else {reject and stop}
 }

Optimization of a single filter is expressed below in equation format. For each bit position of the filter, j , if the bits, m_j , of all the wanted messages, M_w , are identical, then
10 set the corresponding filter components, f_j , to these values; else, set the value to an X,
e.g., "don't care." That is, for ($j = 0, j < n, j++$)

$$\left\{ \begin{array}{ll} \forall m \in M_w: & \\ \text{if } (f_j == m_j) & \{f_j = m_j\} \\ \text{else} & \{f_j = X\} \end{array} \right\}$$

15 In an optimal setting for an P-filter set, i.e., $F = \{F_1, F_2, \dots, F_P\}$, the solution comprises testing all the possible configurations of the filters and then choosing the one that incorporates the desired constraint.

One embodiment of the present invention proposes a method for configuring a
20 two-filter set, i.e., $F = \{F_1, F_2\}$. Preferably, one of the filters is initialized and configured to accept a wanted message. The single filter is then optimized and configured to accept all the wanted messages. Both filters are then set equal to each other. The first and second filter compose a first set of filters. The first set of filters is configured to accept all the wanted messages. To configure each possible configuration for the first set of
25 filters, each filter component defined as X is alternatively defined in F_1 and F_2 . That is, set the X-defined component of F_1 to 0 and set the corresponding X-defined component of F_2 to 1. Then, for both F_1 and F_2 , optimize each filter individually so that all wanted messages will be accepted by the two-filter set. The selected filter setting is chosen based on an application-dependent constraint, e.g., the one that minimizes the number of
30 unwanted messages that are not rejected. The following example is provided to show the configuring of filters for a 1, 2 and 3 filter set.

M_w represents a set of wanted messages, i.e., $M_w = \{m_1, m_2, m_3, m_4, m_5, m_6\}$, wherein $m_1 = 0011\ 0100\ 1001$; $m_2 = 1010\ 0010\ 1010$; $m_3 = 1110\ 0001\ 1100$; $m_4 = 0101\ 0110\ 1000$; $m_5 = 1000\ 1001\ 1000$; and $m_6 = 0011\ 0101\ 1010$.

35 Configuring a single filter to accept all of the wanted messages above, results in $F_1 = XXXX\ XXXX\ 1XXX$. Thus, 2^{11} possible messages can cross the bus. Of these messages, only 6 are wanted messages. Although there is a large amount of messages

5 that are allowed to pass through F_1 , it is still significantly less than allowing all messages to pass through, i.e. 2^{12} .

Utilizing the same wanted messages for the single filter example shown above, a further example is now provided for a two filter set. Preferably, the first filter, F_1 , is initialized and set equal to a wanted message. F_1 is then optimized wherein its bits are set 10 to a value that will allow F_1 to accept every wanted message. In this example, $F_1 = \text{XXXX XXXX } 1\text{XXX}$. A second filter, F_2 , is set equal to F_1 , i.e., $F_1 = F_2 = \text{XXXX XXXX } 1\text{XXX}$. The filters are then configured to determine potential configurations of the first filter set, F_1 and F_2 . The potential configurations for the first filter set are determined by individually replacing each X with a 0 for F_1 , and a 1 for each 15 corresponding X of F_2 :

	1st case:	$\{F_1 = 0\text{XXX XXXX } 1\text{XXX}, F_2 = 1\text{XXX XXXX } 1\text{XXX}\},$
	2nd case:	$\{F_1 = X0XX XXXX 1\text{XXX}, F_2 = X1XX XXXX 1\text{XXX}\},$
	3rd case:	$\{F_1 = XX0X XXXX 1\text{XXX}, F_2 = XX1X XXXX 1\text{XXX}\},$
	4th case:	$\{F_1 = XXX0 XXXX 1\text{XXX}, F_2 = XXX1 XXXX 1\text{XXX}\},$
20	5th case:	$\{F_1 = \text{XXXX } 0\text{XXX } 1\text{XXX}, F_2 = \text{XXXX } 1\text{XXX } 1\text{XXX}\},$
	6th case:	$\{F_1 = \text{XXXX } X0XX } 1\text{XXX, F_2 = \text{XXXX } X1XX } 1\text{XXX\},$
	7th case:	$\{F_1 = \text{XXXX } XX0X } 1\text{XXX, F_2 = \text{XXXX } XX1X } 1\text{XXX\},$
	8th case:	$\{F_1 = \text{XXXX } XXX0 } 1\text{XXX, F_2 = \text{XXXX } XXX1 } 1\text{XXX\},$
	9th case:	$\{F_1 = \text{XXXX } XXXX } 10\text{XX, F_2 = \text{XXXX } XXXX } 11\text{XX\},$
25	10th case:	$\{F_1 = \text{XXXX } XXXX } 1X0X, F_2 = \text{XXXX } XXXX } 1X1X\},$
	11th case:	$\{F_1 = \text{XXXX } XXXX } 1XX0, F_2 = \text{XXXX } XXXX } 1XX1\}.$

In this example, there are 11 potential configurations for the first filter set. Below is a listing that shows the wanted messages accepted by each potential filter set 30 configuration:

	1st potential configuration:	$\{F_1 \text{ accepts } (m_1, m_4, m_6), F_2 \text{ accepts } (m_2, m_3, m_5)\},$
	2nd potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_5, m_6), F_2 \text{ accepts } (m_3, m_4)\},$
	3rd potential configuration:	$\{F_1 \text{ accepts } (m_4, m_5), F_2 \text{ accepts } (m_1, m_2, m_3, m_6)\},$
	4th potential configuration:	$\{F_1 \text{ accepts } (m_2, m_3, m_5), F_2 \text{ accepts } (m_1, m_4, m_6)\},$
35	5th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_3, m_4, m_6), F_2 \text{ accepts } (m_5)\},$
	6th potential configuration:	$\{F_1 \text{ accepts } (m_2, m_3, m_5), F_2 \text{ accepts } (m_1, m_4, m_6)\},$
	7th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_3, m_5, m_6), F_2 \text{ accepts } (m_2, m_4)\},$
	8th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_4), F_2 \text{ accepts } (m_3, m_5, m_6)\},$
	9th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_4, m_5, m_6), F_2 \text{ accepts } (m_3)\},$
40	10th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_3, m_4, m_5), F_2 \text{ accepts } (m_2, m_6)\},$
	11th potential configuration:	$\{F_1 \text{ accepts } (m_2, m_3, m_4, m_5, m_6), F_2 \text{ accepts } (m_1)\}.$

Each filter for each potential configuration is then separately optimized, resulting

5 in the following potential configurations of F_1 and F_2 below:

1st potential configuration: $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$,
2nd potential configuration: $\{F_1 = X0XX\ XXXX\ 10XX, F_2 = X1XX\ 0XXX\ 1X00\}$,
3rd potential configuration: $\{F_1 = XX0X\ XXXX\ 1000, F_2 = XX1X\ 0XXX\ 1XXX\}$,
4th potential configuration: $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 01X1\ 0100\ 10XX\}$,
10 5th potential configuration: $\{F_1 = XXXX\ 0XXX\ 1XXX, F_2 = 1000\ 1001\ 1000\}$,
6th potential configuration: $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 0XX1\ 01XX\ 10XX\}$,
7th potential configuration: $\{F_1 = XXXX\ XX0X\ 1XXX, F_2 = 0000\ 0X10\ 10X0\}$,
8th potential configuration: $\{F_1 = XXXX\ 0XX0\ 10XX, F_2 = XXXX\ XXX1\ 1XX0\}$,
9th potential configuration: $\{F_1 = XXXX\ XXXX\ 10XX, F_2 = 1110\ 0001\ 1100\}$,
15 10th potential configuration: $\{F_1 = XXXX\ XXXX\ 1X0X, F_2 = X01X\ 0XXX\ 1010\}$,
11th potential configuration: $\{F_1 = XXXX\ XXXX\ 1XX0, F_2 = 0011\ 0100\ 1001\}$.

The number of unwanted messages accepted in each optimized case above is:

1st optimized potential configuration: $2^6 + 2^6 - 6$
20 2nd optimized potential configuration: $2^9 + 2^7 - 6$
3rd optimized potential configuration: $2^6 + 2^9 - 6$
4th optimized potential configuration: $2^7 + 2^3 - 6$
5th optimized potential configuration: $2^{10} + 2^0 - 6$
25 6th optimized potential configuration: $2^7 + 2^6 - 6$
7th optimized potential configuration: $2^{10} + 2^2 - 6$
8th optimized potential configuration: $2^8 + 2^9 - 6$
9th optimized potential configuration: $2^{10} + 2^0 - 6$
10th optimized potential configuration: $2^8 + 2^5 - 6$
30 11th optimized potential configuration: $2^{10} + 2^0 - 6$

The optimized potential configuration for the first set of filters is chosen based on a selection criteria. One preferred selection criteria is to minimize the amount of unwanted messages allowed to pass through the first set of filters. To achieve this desired result, the 1st optimized potential configuration should be selected, i.e., $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$. A comparison between the filtering capability of the single filter and the dual filter set is: $(2^{11} - 6) / (2^6 + 2^6 - 6)$; a reduction of approximately 16 times less messages.

In addition to the selection criteria, other known information can affect the selection of the filter set to be utilized. For example, it may be known that a particular 40 unwanted message has a higher probability of occurring over other unwanted messages. Thus, a filter set configuration should be chosen that will reject this specific unwanted message; even though in theory, the selected configuration potentially allows more unwanted messages to pass through the filter configuration.

5 For a three filter set configuration, i.e., $F = \{F_1, F_2, F_3\}$; it is preferable to utilize
the optimized two filter configuration, if available — in this example, case 1 would be
utilized. However, any of the determined two filter configurations can be utilized with
the third filter. Each of the 11 potential two-filter configuration cases determined earlier
and shown below can be utilized with the third filter to determine a desired configuration
10 for the three-filter set:

1st case: $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$,
2nd case: $\{F_1 = X0XX\ XXXX\ 10XX, F_2 = X1XX\ 0XXX\ 1X00\}$,
3rd case: $\{F_1 = XX0X\ XXXX\ 1000, F_2 = XX1X\ 0XXX\ 1XXX\}$,
4th case: $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 01X1\ 0100\ 10XX\}$,
15 5th case: $\{F_1 = XXXX\ 0XXX\ 1XXX, F_2 = 1000\ 1001\ 1000\}$,
6th case: $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 0XX1\ 01XX\ 10XX\}$,
7th case: $\{F_1 = XXXX\ XX0X\ 1XXX, F_2 = 0000\ 0X10\ 10X0\}$,
8th case: $\{F_1 = XXXX\ 0XX0\ 10XX, F_2 = XXXX\ XXX1\ 1XX0\}$,
9th case: $\{F_1 = XXXX\ XXXX\ 10XX, F_2 = 1110\ 0001\ 1100\}$,
20 10th case: $\{F_1 = XXXX\ XXXX\ 1X0X, F_2 = X01X\ 0XXX\ 1010\}$,
11th case: $\{F_1 = XXXX\ XXXX\ 1XX0, F_2 = 0011\ 0100\ 1001\}$.

Utilizing F_1 and F_2 of the selected two filter configuration, a third filter, F_3 , is set equal to
 F_1 wherein F_1 , F_2 , and F_3 compose a second filter set having F_1 equal to F_3 . A third filter
25 set is also composed wherein its third filter, F_3 , is set equal to the second filter, F_2 ; thus,
the third filter set comprises F_1 , F_2 , and F_3 wherein F_2 and F_3 are equal.

Thus, third filter, F_3 , is associated with each case wherein a second filter set and a
third filter set are constructed. The second and third filter sets each comprise three filters,
 F_1 , F_2 , and F_3 . F_1 and F_3 of the second filter set are set equal to each other; and F_3 is set
30 equal to F_2 of the third filter set. Beginning with the first case, $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$, the initial configurations of the second filter set are
configured by individually setting each undefined component of F_1 to 0 and each
corresponding undefined filter component of F_3 to 1, respectively, as follows:

1st case, subcase1: $\{F_1 = 00X1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 01X1\ 01XX\ 10XX\}$
35 1st case, subcase2: $\{F_1 = 0X01\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0X11\ 01XX\ 10XX\}$,
1st case, subcase3: $\{F_1 = 0XX1\ 010X\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0XX1\ 011X\ 10XX\}$,
40 1st case, subcase4: $\{F_1 = 0XX1\ 01X0\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0XX1\ 01X1\ 10XX\}$,

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5 1st case, subcase5: { $F_1 = 0XX1\ 01XX\ 100X$, $F_2 = 1XX0\ X0XX\ 1XX0$, $F_3 = 0XX1\ 01XX\ 101X$ },
1st case, subcase6: { $F_1 = 0XX1\ 01XX\ 10X0$, $F_2 = 1XX0\ X0XX\ 1XX0$, $F_3 = 0XX1\ 01XX\ 10X1$ }.

10 The same is done for F_1 and F_3 of the third filter set:

1st case, subcase7:

{ $F_1 = 0XX1\ 01XX\ 10XX$, $F_2 = 1XX0\ X0XX\ 1XX0$, $F_3 = 11X0\ X0XX\ 1XX0$ },

1st case, subcase8:

15 { $F_1 = 0XX1\ 01XX\ 10XX$, $F_2 = 1X00\ X0XX\ 1XX0$, $F_3 = 1X10\ X0XX\ 1XX0$ },

1st case, subcase9:

{ $F_1 = 0XX1\ 01XX\ 10XX$, $F_2 = 1XX0\ 00XX\ 1XX0$, $F_3 = 1XX0\ 10XX\ 1XX0$ },

1st case, subcase10:

{ $F_1 = 0XX1\ 01XX\ 10XX$, $F_2 = 1XX0\ X00X\ 1XX0$, $F_3 = 1XX0\ X01X\ 1XX0$ },

20 1st case, subcase11:

{ $F_1 = 0XX1\ 01XX\ 10XX$, $F_2 = 1XX0\ X0X0\ 1XX0$, $F_3 = 1XX0\ X0X1\ 1XX0$ },

1st case, subcase12:

{ $F_1 = 0XX1\ 01XX\ 10XX$, $F_2 = 1XX0\ X0XX\ 10X0$, $F_3 = 1XX0\ X0XX\ 11X0$ },

1st case, subcase13:

25 { $F_1 = 0XX1\ 01XX\ 10XX$, $F_2 = 1XX0\ X0XX\ 1X00$, $F_3 = 1XX0\ X0XX\ 1X10$ }.

The process continues for each subsequent case until all 11 potential filter configurations have been done. A three-filter set is then selected from all the cases and subcases determined in accordance with the selection criteria.

30 It is to be understood that the present invention is applicable for an P-filter set ($P > 3$); i.e., $F = \{F_1, F_2, \dots, F_P\}$ wherein optimization of each potential filter set configuration is recursively determined via the steps shown above and the selected P-filter setting is chosen based on any constraints of the selection criteria.

35 While specific embodiments and exemplifications of the present invention have been illustrated and described, numerous modifications are possible without departing from the scope or spirit of the invention.